

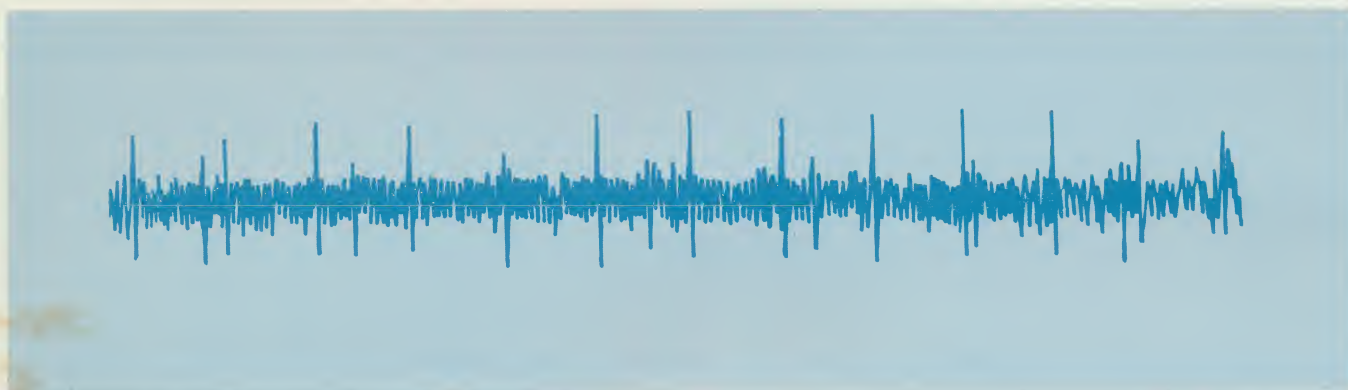
M NEMOTRON



COMPUTER OF AVERAGE TRANSIENTS CAT 400 B

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FETAL ECG SIGNAL



AFTER 50 SWEEPS



AFTER 100 SWEEPS

SEE REFERENCE (31) IN SELECTED REFERENCES.

INTRODUCTION

NOISE IS AN INESCAPABLE PHENOMENON OF NATURE. It manifests itself wherever a measurement is made and masks the variable being measured. The MNEMOTRON Computer of Average Transients—CAT—is a multi-purpose digital computer which isolates and measures small, repetitive electrical signals which are masked by background noise. So long as the noise is random in nature, information theory shows that the definition of the signal may be improved by an amount proportional to the number of repetitions. This is precisely what the CAT does; it performs a summation function which adds individual signals and computes their average. The desired signal adds arithmetically since it occurs in reproducible phase and, in effect, tends to cancel the out-of-phase background noise.

Averaging techniques based on analog devices have been used for some time to improve signal detection. The application of digital computers for this purpose dates to the design and operation of the ARC computer at MIT in 1958. The application of that computer to the averaging of evoked potentials in the brain, pioneered by the communications Biophysics group, provided promising new techniques for analysis of the electrical activity of the brain.

The CAT computer, produced by the MNEMOTRON Division of Technical Measurement Corporation, provides the averaging functions of the earlier ARC computer in an improved device which offers greater flexibility, compactness, and simplicity of operation. This precision instrument, which contains stored programs for the computation of averaged responses, time interval histograms, and amplitude histograms, constitutes the keystone of a data processing system. In keeping with a "building block" concept, custom designed accessories are available which further extend the capabilities of the CAT. Now, research personnel have available a reliable system for rapid on-line data processing, which is completely compatible with conventional commercial equipment.

AVERAGING FOR DETECTION AND PRECISE DEFINITION OF RESPONSES

The presence of small signals obscured by noise may be reliably detected, and the time and amplitude characteristic of such signals delineated, with a resolution several orders of magnitude above what is otherwise possible. For example; in the evoked brain potential experiment, a resolution of 0.01 microvolt is readily obtained. Or, with averaging of pupil responses to sound stimuli, using the Lowenstein Pupillometer, a resolution of 0.00002 inches is obtained in the measurement of dynamic responses of the pupil diameter.

The MNEMOTRON Computer of Average Transients—CAT—is a multi-purpose digital computer capable of isolating and evaluating small electrical responses masked by random background noise. This is done on-line, permitting the investigator to monitor and adjust parameters of the experiment while in progress. A summation (averaging) technique is automatically programmed which phase-locks the desired signal with relation to a known stimulus or reference pulse and sums successive responses.

The CAT incorporates its own analog-to-digital converters, providing for the analysis of analog input signals on-line. The CAT outputs provide both digital and analog data for subsequent analysis. A three-inch oscilloscope continuously displays the CAT memory contents during accumulation and display modes.

Digital output in binary-coded-decimal (BCD) form can be used with such MNEMOTRON units as the Model 500 Paper Tape Printer, the Model 510 Typewriter Drive Unit for IBM typewriter print-outs, or the Model 520 Type-Punch-Read Control Unit for punch-read devices.

An analog output is provided for use with strip-chart recorders and X-Y plotters.

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INTRODUCTION

MEDICAL RESEARCH APPLICATIONS OF AVERAGING RESPONSES

BRAIN FUNCTION

The study of evoked electric potentials in different brain structures is a powerful tool for obtaining increased insight into the processing of information by the brain. When recorded from scalp electrodes, these potentials evoked by various sensory stimuli are too small to be recognized in the total ongoing electric activity of the brain (EEG). The evoked potentials, as recorded with scalp electrodes, are only a few microvolts and have a duration of a fraction of a second. The shapes of the evoked potentials and the latencies and durations vary with the type of sensory stimulation and with the position of the electrodes. Evoked potentials spread and travel from one part of the brain to another. By means of several simultaneous averaging processes with separate electrodes, the way in which the evoked potential travels can be mapped.

This spread and transformation of evoked potentials in brain space constitutes an important measure which can also, under some circumstances, be related to conditioning and learning. Certain drugs selectively affect the manner of occurrence of evoked potentials in different brain areas.

The decision-making aspects of brain functioning may be studied by observing average evoked responses when right decisions are made as compared with similar averages for wrong responses.

NERVE ACTION POTENTIAL SHAPES AND PATTERNS

at known times. By averaging times of occurrence of nerve action potentials, studies can be made relating the firing patterns to changes in experimental conditions and stimuli. The changes in the shape of the action potential may also be studied by averaging.

The pattern of firing of given nerve fibres may be determined even in the presence of firing by other unstimulated fibres, when stimuli occur

PERCEPTION OF SENSORY STIMULI

in the brain and its various substructures. Thus, a relation may be developed between the psychologic and physiologic fields of observation. Studies of the motion of visual stimuli and corresponding evoked potentials are also possible.

In the study of perception of stimuli such as light, sound, touch, taste and smell, a relation can be determined between the psychosensory threshold and intensity levels and the corresponding evoked potentials.

REFLEX REACTIONS

The dynamic pattern of reflex reactions may be studied by averaging reflex responses. Such an approach is useful for clearly defining the reflex response shapes, such as pupillary reflexes to light and to sound, the psychogalvanic skin response, and various cardiovascular reflexes. By averaging successive groups of reflexes, studies of adaptation and conditioning can be undertaken.

DESIGN FEATURES

PORTABILITY

THE COMPUTER OF AVERAGE TRANSIENTS IS DESIGNED FOR USE WITHIN THE IMMEDIATE AREA OF EXPERIMENTATION. THE UNIT, WEIGHING 38 POUNDS, AND OCCUPYING A SPACE 8-1/2 X 10-1/2 X 22 INCHES CAN EASILY BE TRANSPORTED TO ANY LOCATION FOR A VARIETY OF APPLICATIONS.

FLEXIBILITY

EXPERIMENTAL PROCEDURES INCORPORATING THE CAT MAY BE MODIFIED BY THE OPERATOR AT ANY TIME DURING THE INVESTIGATION. THIS PROVIDES CONSIDERABLE FLEXIBILITY IN ITS OPERATION AND REQUIRES NO SPECIAL PROGRAMMING TECHNIQUES.

EXTERNAL CONNECTIONS

EXTERNAL CONNECTIONS ON THE INSTRUMENT ARE AVAILABLE TO PERMIT OPERATION FROM REMOTE EQUIPMENT. PROVISIONS ARE ALSO AVAILABLE FOR THE USE OF EXTERNAL STIMULI FOR REFERENCE PULSES AS WELL AS INTERNAL STIMULI CAPABLE OF ACTIVATING REMOTE ANCILLARY INSTRUMENTATION.

MEMORY CAPABILITY

THE CAT IS COMPOSED OF A MAGNETIC CORE SYSTEM IN WHICH THE DATA ARE STORED IN BCD FORM. THERE ARE 400 MEMORY ADDRESSES, EACH CAPABLE OF STORING 20 BINARY DIGITS (BITS) REPRESENTING A COUNT OF 10^5-1 IN DECIMAL FORM. TOTAL MEMORY CONSISTS OF 8000 CORES. MEMORY ADDRESSES CAPABLE OF STORING 24 BITS (10^6-1) ARE ALSO AVAILABLE.

ADD OR SUBTRACT FEATURE

MEMORY INFORMATION CAN BE STORED IN EITHER AN ADD OR SUBTRACT MODE. THIS FEATURE PERMITS A RESPONSE SIGNAL TO BE ADDED TO OR SUBTRACTED FROM THE DATA ALREADY EXISTING IN THE CAT MEMORY.

OSCILLOSCOPE DISPLAY

A 3-INCH HIGH-RESOLUTION CRT INTEGRAL TO THE UNIT IS PROVIDED TO MONITOR THE DATA ACCUMULATED IN THE MEMORY SYSTEM. IT GIVES AN ANALOG DISPLAY OF THE STORED INFORMATION AND CAN EASILY BE ADJUSTED FOR SIGNAL DELINEATION. PROVISIONS ARE AVAILABLE IN THE MODEL 400B FOR SLAVED OPERATION OF EXTERNAL OSCILLOSCOPE EQUIPMENT.

ADDRESS IDENTIFICATION

ALTERNATE GROUPS OF 10 ADDRESSES ARE INTENSIFIED FOR EASIER IDENTIFICATION OF DATA LOCATION WITHIN THE CAT MEMORY.

INPUT ADAPTABILITY

ONE, TWO, OR FOUR INPUT SELECTIONS CAN BE OBTAINED WHICH PERMIT PROCESSING OF INDIVIDUAL OR UP TO FOUR SIMULTANEOUS OR CONSECUTIVE RESPONSE SIGNALS. OUTPUTS CLEARLY DEFINE EACH SIGNAL AND THE CRT SIMULTANEOUSLY DISPLAYS THE SEPARATE AND DISTINCT RESPONSES.

TRANSISTORIZATION

THE INSTRUMENT IS COMPLETELY TRANSISTORIZED. ALL COMPONENTS ARE MOUNTED ON PRINTED CIRCUIT BOARDS TO INSURE RELIABLE OPERATION UNDER RUGGED ENVIRONMENTAL CONDITIONS.

PLUG-IN CARDS

PLUG-IN CIRCUIT BOARD CARDS ARE USED THROUGHOUT THE UNIT, PROVIDING SIMPLE REPLACEMENT WHEN NECESSARY. EXTENSION CARDS ARE PROVIDED FOR TESTING PLUG-IN CARDS WHILE THE CAT IS OPERATING.

ACCESSORY INTEGRATION

THE CAT SERIES 600 ACCESSORIES HAVE BEEN DESIGNED FOR USE WITH THE MNEMOTRON COMPUTER OF AVERAGE TRANSIENTS. THEY PROVIDE THE CAT WITH ADDITIONAL FEATURES WHICH GREATLY EXPAND ITS CAPABILITIES AND OPERATION.

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Selects number of inputs; 1, 2 or 4. Divides 400 CAT addresses by number of inputs

Determines delay time between internal or external trigger and start of analysis sweep. Sweep starts immediately if in 0 position. Adjustable delay time between 0.1 second and 10 seconds

Provides plus 50 volt pulse. This may occur at the start of an analysis sweep (PROMPT) or at the 20th address (ORD 20)

CRT Amplitude Control

Cathode-Ray Tube Controls

Expands display trace

Positions traces horizontally

Selects analysis sweep time in seconds for 400 ordinates

Calibrated display and analog output amplitude control

At EXT., an external pulse of at least plus 2 volts applied at rear starts CAT operation. At INT., CAT automatically continues to sweep

Erases information stored in memory

Set to PLOT for analog readout and to PRINT for digital readout

Stops all modes of operation

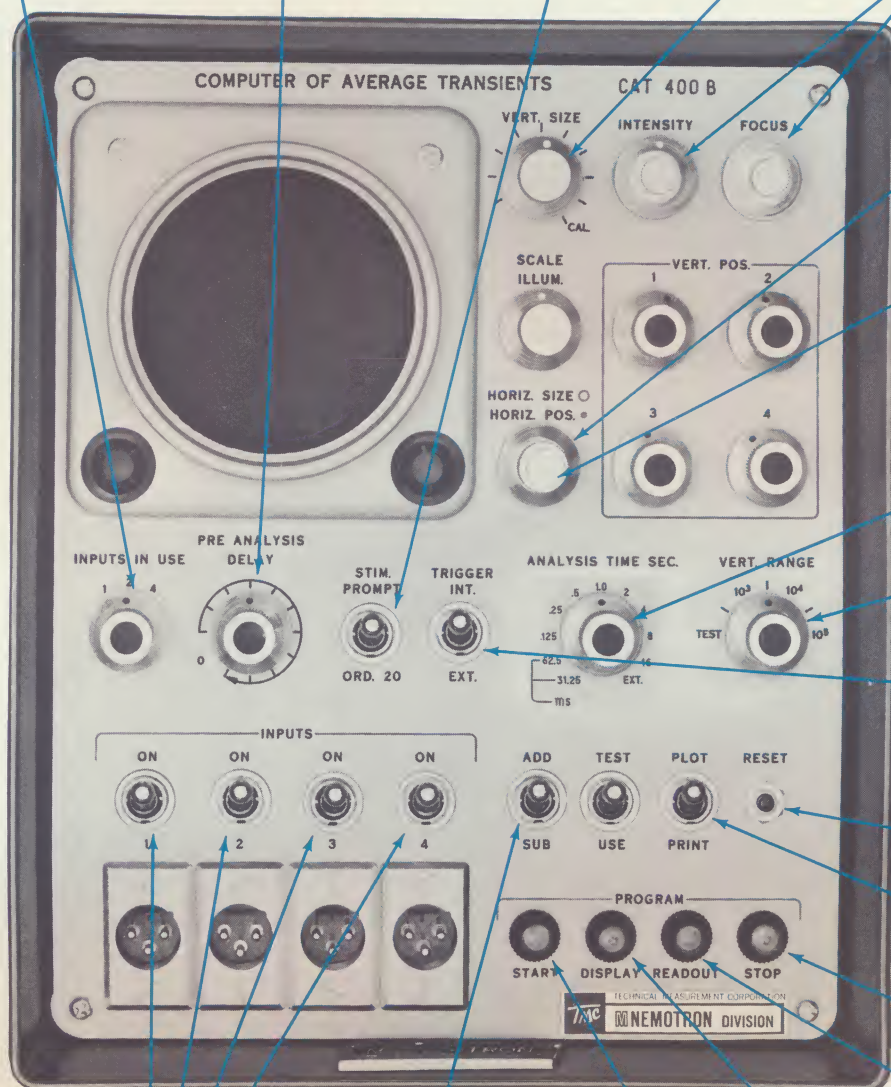
Initiates readout

Displays information stored in memory

Starts analysis sweep and accumulation of information

Selects mode of data storage

Disables individual inputs when not in the ON position



MODEL CAT 400B
FRONT PANEL CONTROLS

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SPECIFICATIONS

EXTERNAL TRIGGER

RISE TIME	Less than 10 microseconds
MINIMUM INPUT VOLTAGE	Plus 2 volts
MAXIMUM REPETITION RATE	50 pps (10,000 pps for histograms)

EXTERNAL ADDRESS ADVANCE

RISE TIME	Less than 10 microseconds
MINIMUM INPUT VOLTAGE	Plus 1 volt
MAXIMUM REPETITION RATE	20,000 pps (800,000 pps for histograms)

EXTERNAL ADDRESS RESET

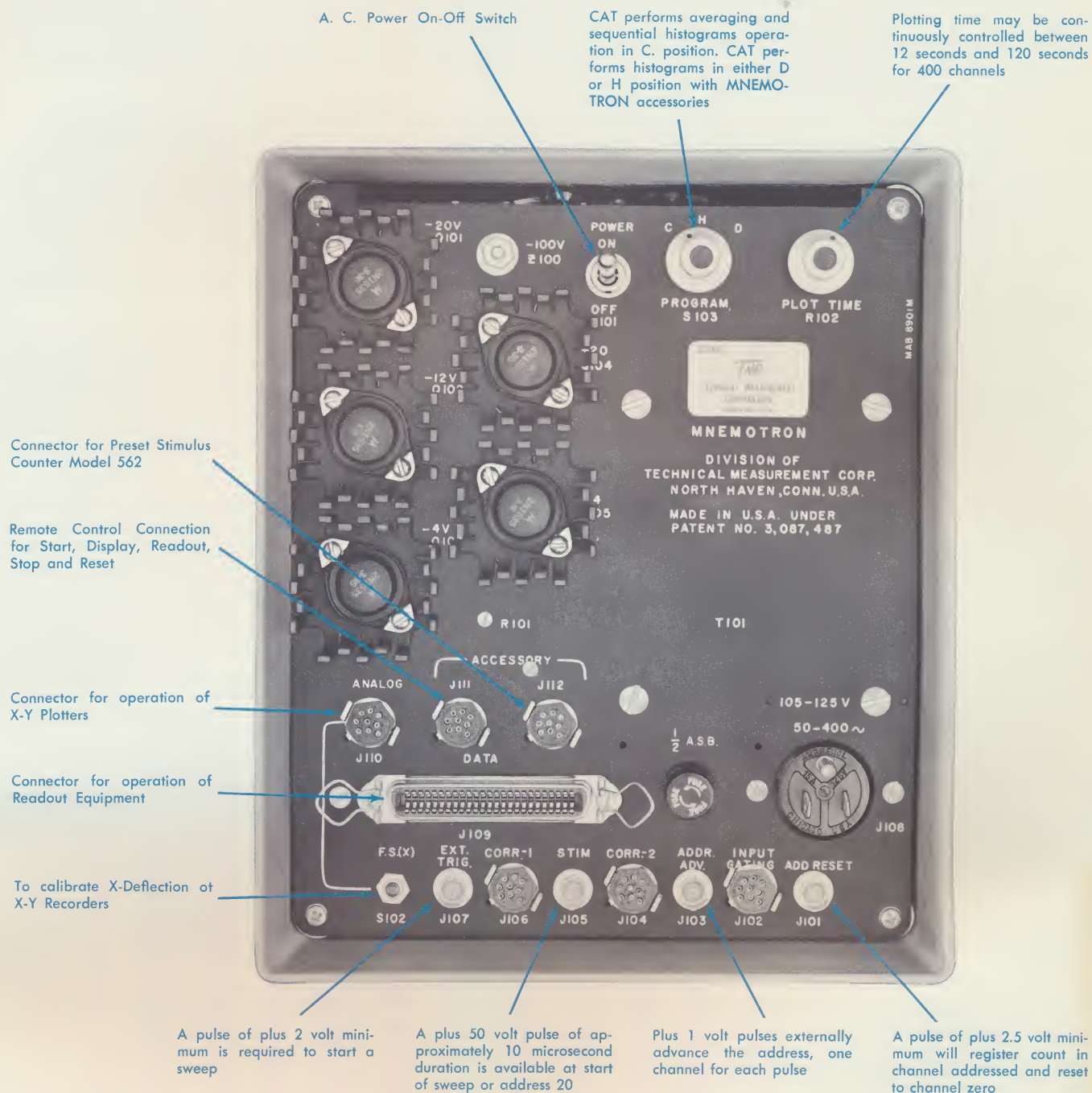
RISE TIME	Less than 10 microseconds
MINIMUM INPUT VOLTAGE	Plus 1 volt
MAXIMUM REPETITION RATE	10,000 pps (for histograms only)

POWER REQUIREMENTS

VOLTAGE	100, 115, 200, 215 or 230 volts ac
FREQUENCY	50 to 400 cps
POWER	30 watts (approximately)
DC OPERATION	DC to AC converter available

PHYSICAL DIMENSIONS

WIDTH	8-1/2 inches
HEIGHT	10-1/2 inches
LENGTH	22 inches
WEIGHT	38 pounds (approximately)



MODEL CAT 400B
REAR PANEL CONTROLS

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PRINCIPLES OF OPERATION

The Computer of Average Transients—CAT—is a highly flexible, research oriented, multi-purpose on-line digital computer which serves as the keystone of a completely compatible data processing system utilizing a "building block" concept.

The CAT applies averaging techniques to improve the signal-to-noise ratio by repeated additions of data samples. Each addition cycle is initiated by a synchronizing signal which is simultaneous with the beginning of a segment of data. The coherent portions of the data samples, which are phase-locked to the synchronizing signals, sum algebraically with each repetition; the non-coherent components of the data, or noise, do not add in reproducible phase, and therefore tend to diminish as the number of repetitions increases.

The CAT, when triggered by the sync signal, samples the data at specified intervals, converting each sample into a digital number of counts proportional to the data amplitude. These counts are then stored in a particular address in a magnetic core memory, after being added to the number previously stored in this address. Each memory address thus corresponds to a particular time after the synchronizing signal, and the number stored in that address represents the average data amplitude at that time. Since the noise is not phase-locked, it adds in a RMS fashion, while the coherent component summates algebraically. Averaging thus results in an improvement of the signal-to-noise ratio by an amount proportional to the number of repetitions.

The illustration depicts a simplified block diagram of the Computer of Average Transients. It includes the major portions involved in the CAT signal averaging process.

The synchronization signal is either externally fed to the trigger input or internally generated within the CAT and starts the clock oscillator via the trigger generator. At the same time, the input data signal(s) is (are) fed to the modulator(s). The modulator converts the analog input signal into a discrete number of counts (pulse train) per unit time; the number of counts being proportional to the amplitude of the input signal. This pulse train is routed through the modulator gate which in turn is controlled by the modulator gate control. The modulator gate control circuit selects the proper modulator output that is to be counted in the arithmetic register. The selection is dependent upon the number of inputs in use. The arithmetic register counts these pulses for the time duration selected by analysis time.

The clock oscillator pulses are counted in the address register; the address register selects the memory location in which the counts contained in the arithmetic register are to be stored. Each additional pulse into the address register advances the memory location one address until the 400th address has been reached. At this point, the address register is reset to zero address and the CAT awaits the next synchronization signal or automatically starts a new sweep. As each address is advanced, the contents stored in that address are read from the memory into the arithmetic register where additional counts are added as a result of the input signal and are then written back into the memory at the same address.

After the data are accumulated, they may be displayed on the CRT integral to the unit or read out in either digital or analog form. In the case of digital readout, the arithmetic data are presented on 20 lines representing five digits in binary-coded-decimal form (BCD) (99,999 maximum). The address data are simultaneously presented on 10 lines representing three digits in BCD form (399 maximum). For analog representation of the memory contents, the digital data are converted through current summing networks and analog voltages are derived, one voltage representing arithmetic information (Y) and one voltage representing address information (X). These voltages are used to deflect the beam of the CRT or to drive an X-Y plotter.

SIMPLIFIED DERIVATION OF SIGNAL-TO-NOISE IMPROVEMENT BY SUMMATION TECHNIQUES

The precise improvement in S/N depends upon the signal variance and the noise bandwidth and amplitude distribution. However, if we assume an invariant signal imbedded in wide-band, constant amplitude noise, then by summing we get:

$$\sum_{j=1}^n S_j = S_1 + S_2 + S_3 + \dots + S_n = nS$$

The noise, being random and hence non-phase-locked, adds in a RMS fashion. That is:

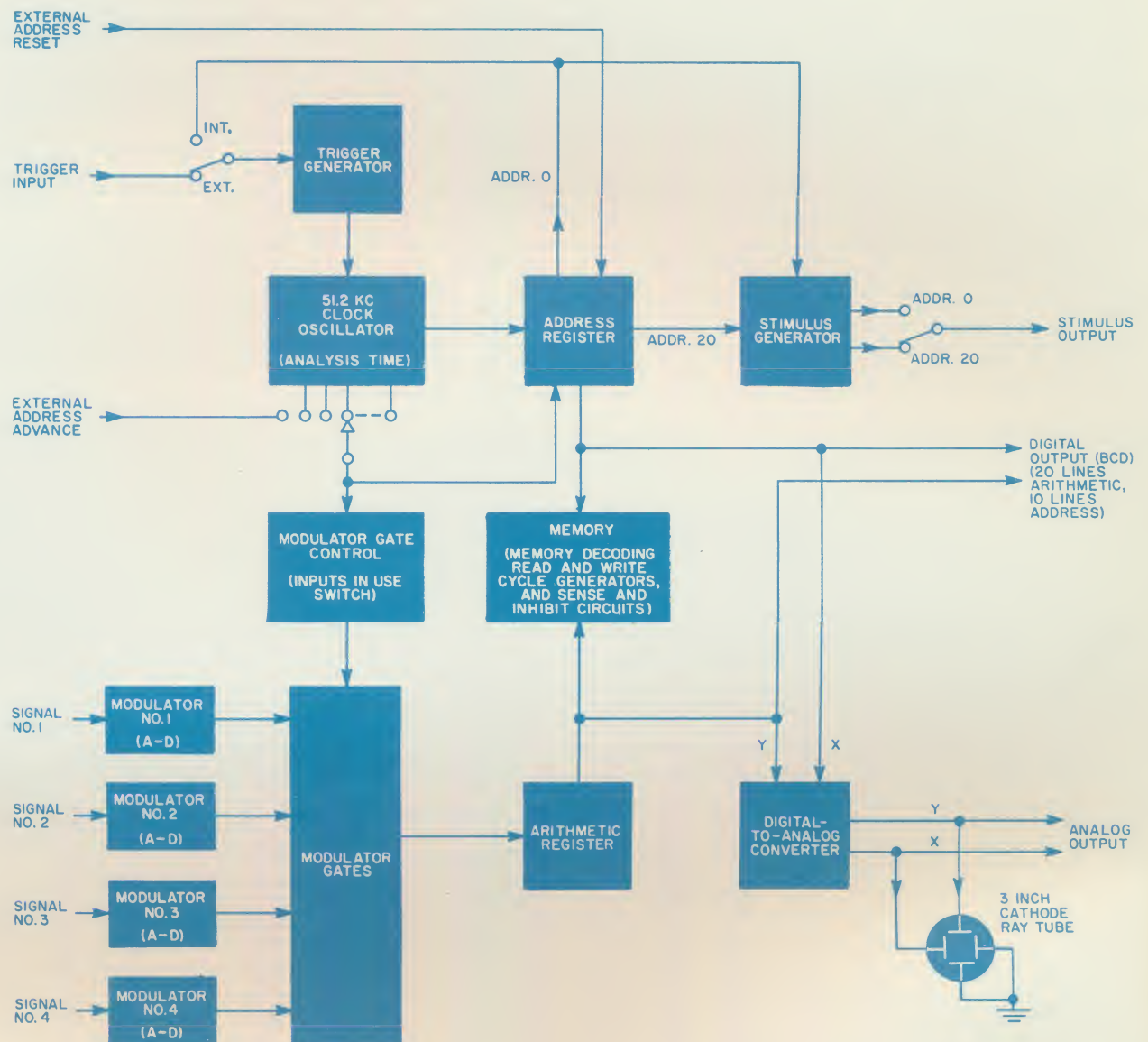
$$\sqrt{\sum_{j=1}^n N_j^2} = \sqrt{N_1^2 + N_2^2 + N_3^2 + \dots + N_n^2} = \sqrt{n} N$$

where n = number of responses summed
 S = amplitude of repetitive signal
 N = amplitude of random noise
 S/N = signal-to-noise ratio of single response

If a ratio is taken of the summed signal and summed noise, it can be seen that the improvement over the original signal-to-noise ratio is by a factor of $\sqrt{n}$.

$$\frac{\sum_{j=1}^n S_j}{\sqrt{\sum_{j=1}^n N_j^2}} = \frac{nS}{\sqrt{n} N} = \sqrt{n} S/N$$

The averaging technique is superior, in most cases, to simple filtering because filtering cannot separate signal from noise when both have the same frequency content.



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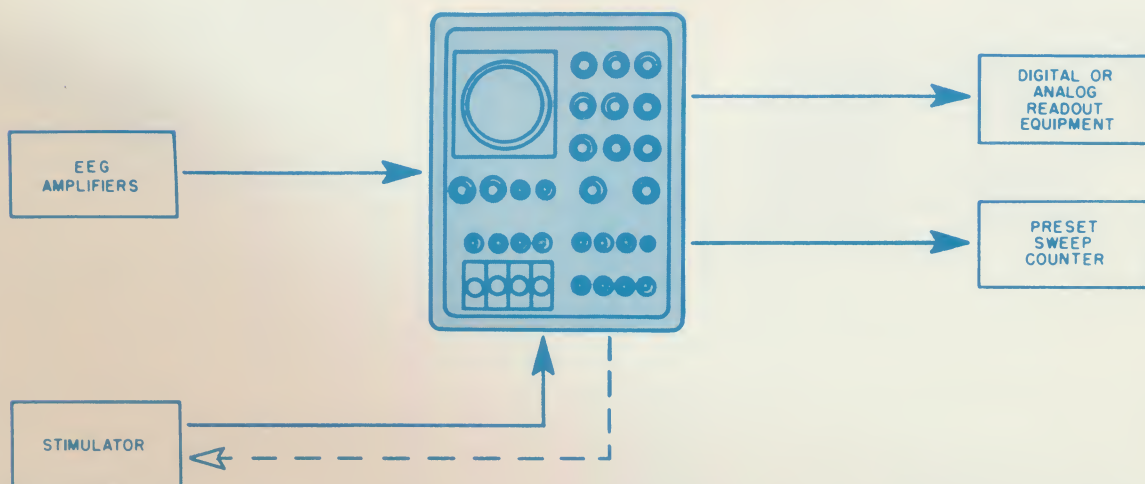
AVERAGING APPLICATIONS

IN EVOKED POTENTIALS

Evoked potentials are the detectable electrical changes of any part of the brain in response to deliberate stimulation. This measurable time-varying neuroelectric waveform is composed of components which are a direct result of stimulation as well as random spontaneous activity. This random activity tends to mask the evoked responses. The CAT is used to isolate those responses under investigation through summation of the stimulus related signals. The random components appear to cancel out as a result of the averaging process. The illustration highlights the response from the brain with its associated stimulus or reference pulse.

As the evoked potentials are summed or averaged, the computed results are immediately displayed on the CRT integral to the CAT — while the computation process is actually occurring. The waveform at the right represents an analog plot from the CAT memory in which the background noise has been reduced.

The block diagram indicates the general arrangement of equipment as used in the evoked potential application. Amplified signals from EEG apparatus are fed to the CAT and a synchronization pulse from a stimulator is used as a triggering device. Data accumulated in the CAT memory may be read out in either analog or digital form for a permanent record for further computer analysis.



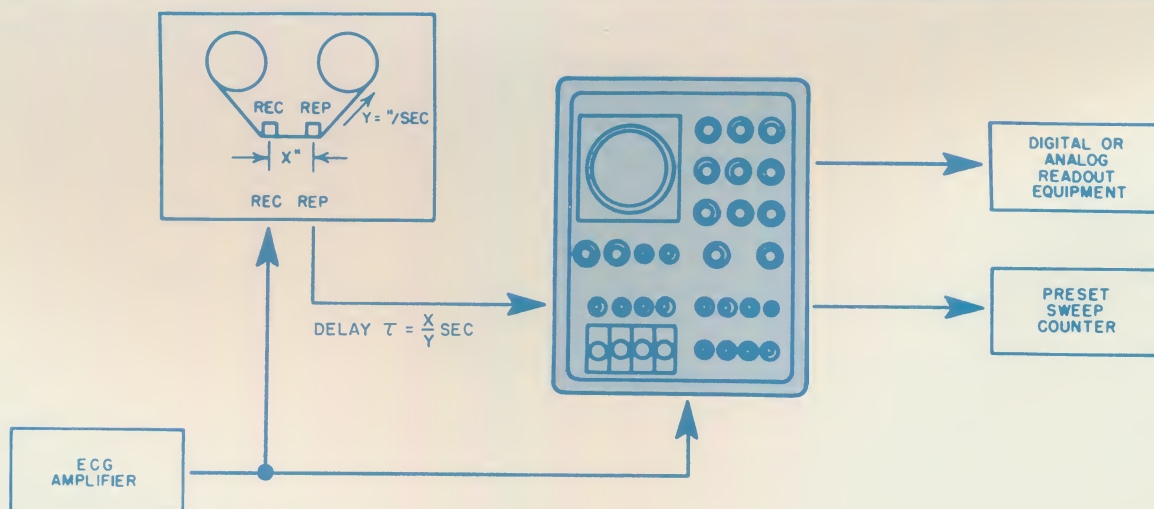
AVERAGING APPLICATIONS

IN CARDIOLOGY

Electrical potentials emanating from the heart reflect the muscle activity of the cardiac cycle. This consists of a repetitive signal in which an unambiguous peak (the R-wave) usually appears as the most prominent point of any cycle, as illustrated. When the overall signal is masked by dense background noise, a reference point must be established for processing the signal in the CAT Computer to isolate the area of interest. Although the R-wave peak provides a naturally occurring reference point, it cannot be used as a reference for the succeeding cycle since the R-R interval varies from one heart beat to another. The interval depends upon such variables as respiration rate and cardiac hyperthermia. A technique therefore is employed by means of a MNEMOTRON magnetic tape recording system which establishes a fixed time delay between the occurrence of each R-wave and its own overall cardiac complex.

The fixed time delay permits CAT averaging of the complete cardiac complex from precisely the same reference point each time. Since the signal under investigation can now be isolated from the random activity, only the desired cardiac potentials are displayed with an integral CRT.

The block diagram indicates the implementation of the time delay technique. The amplified ECG signal is simultaneously fed to both the magnetic tape system and the trigger circuitry of the CAT. A delayed signal is obtained because of the physical separation of the record and reproduce heads. The time delay is inversely proportional to the speed of the tape and directly proportional to the distance between the record and reproduce heads. The delayed signal is fed to the input of the CAT and averaged on command of the R-wave derived time reference signal. Data accumulated in the CAT memory may be read out in digital or analog form into ancillary equipment.



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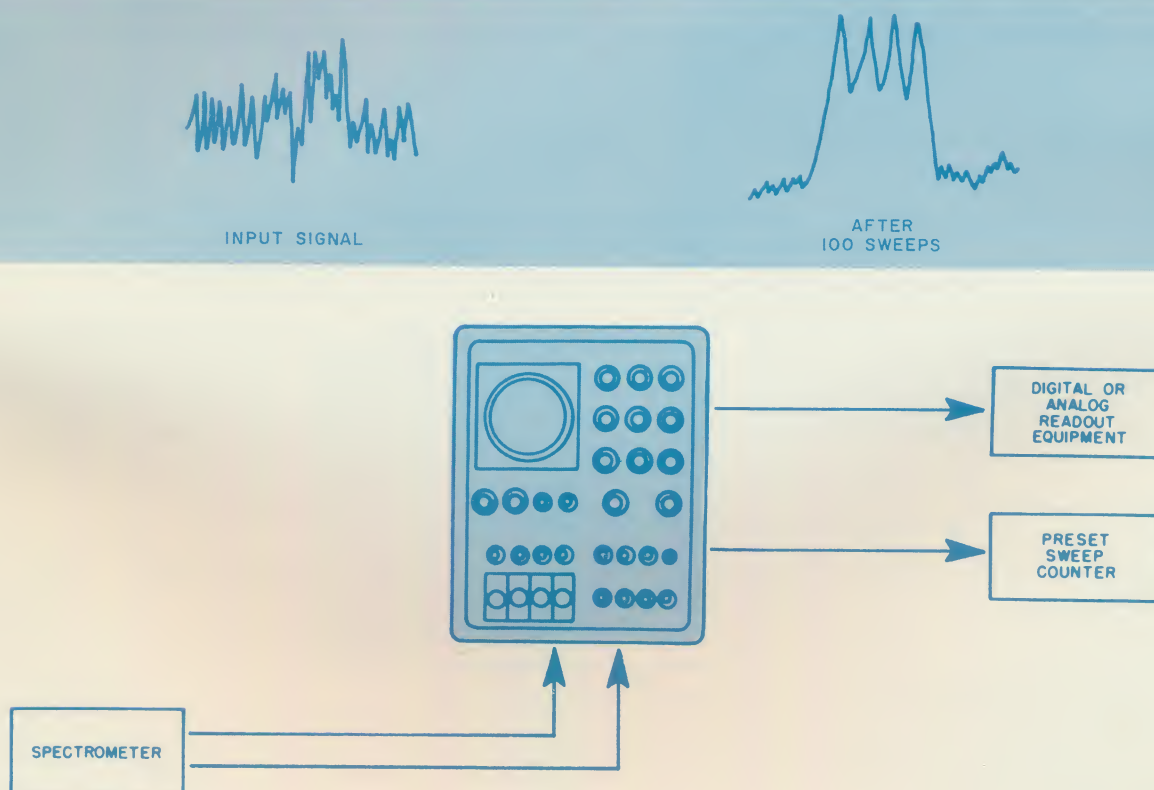
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AVERAGING APPLICATIONS

IN SPECTROSCOPY

The averaging technique has found wide application in many different types of spectroscopy. Spectrophotometry in the infrared, visible, and ultra-violet ranges, nuclear magnetic resonance, electron paramagnetic resonance, raman, and X-ray diffraction spectroscopy are a few such fields. In each of these types of spectroscopy, there is a scanning process in which a sample under investigation is subjected to the appropriate varying field. As the scanning takes place, there is a change in a particular physical characteristic of the sample. There is generally an absorption of energy by the sample, and every different sample has a different pattern associated with it which therefore identifies the elements or compounds contained within the sample. These patterns, or spectra, are formed by detecting the energy absorbed and plotting it as a function of the values of the field which created the absorption. Averaging of the detected signal is often required when working with samples whose spectra are difficult to obtain because of limited quantity, dilution, or other reasons. The CAT offers a successful fulfillment of this particular requirement. Electronic filtering of the signal will often not yield usable results due to the fact that the inherent noise of the system contains the same frequencies as the desired signal.

Averaging is achieved by locking the scanning process of the spectrometer with the accumulation of the signal in the CAT Computer. Provided that the scanning through the spectrum is linear with time, only a synchronization signal is required at the beginning of each scan to initiate the computing process. This synchronization signal can be achieved in several ways. One way is to obtain a signal from a contact closure at the start of the scan if a mechanical device is used to create this scanning process. Another method is to use some unambiguous peak of the signal as a synchronizing reference, provided it occurs prior to the spectral region of interest. Again, as many repetitive scans through the spectrum as necessary are made until the signal-to-noise ratio has sufficiently improved.

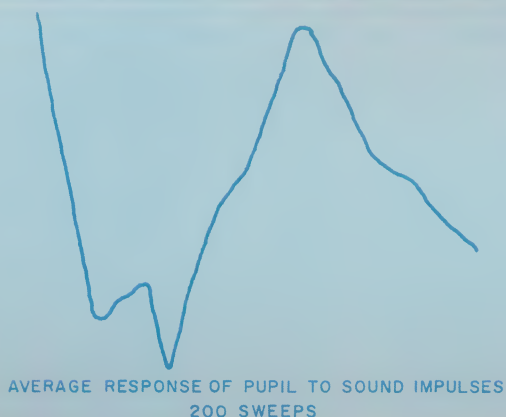


AVERAGING APPLICATIONS

IN PUPILLOGRAPHY

Various physiological and psychological determinations depend upon the sensory stimulation of a subject and monitoring one or more physiological responses. A single response in many cases may not be meaningful since the nature of the response may depend upon parameters not under the control of the experimenter or near-threshold stimulation is used. Pupillography is one area in which averaging has been found quite useful in measuring the response of the pupil (its area) as a result of light flash stimulation. The area of the pupil is measured by detecting the amount of infrared light reflected by the pupil from an infrared source. Since the retina is insensitive to infrared light, it will not effect the response in any way. A signal is derived at the occurrence of the light flash stimulus and serves as the synchronization signal to the CAT Computer. The output of an infrared photo cell detector is amplified and serves as the signal input to the CAT.

These studies are being used to determine the effect of various pharmacological agents on the reflexes of the subject, and also as an aid in the determination of the characteristic transfer function of the visual neurophysiological reflex system.



IN SEISMOLOGY

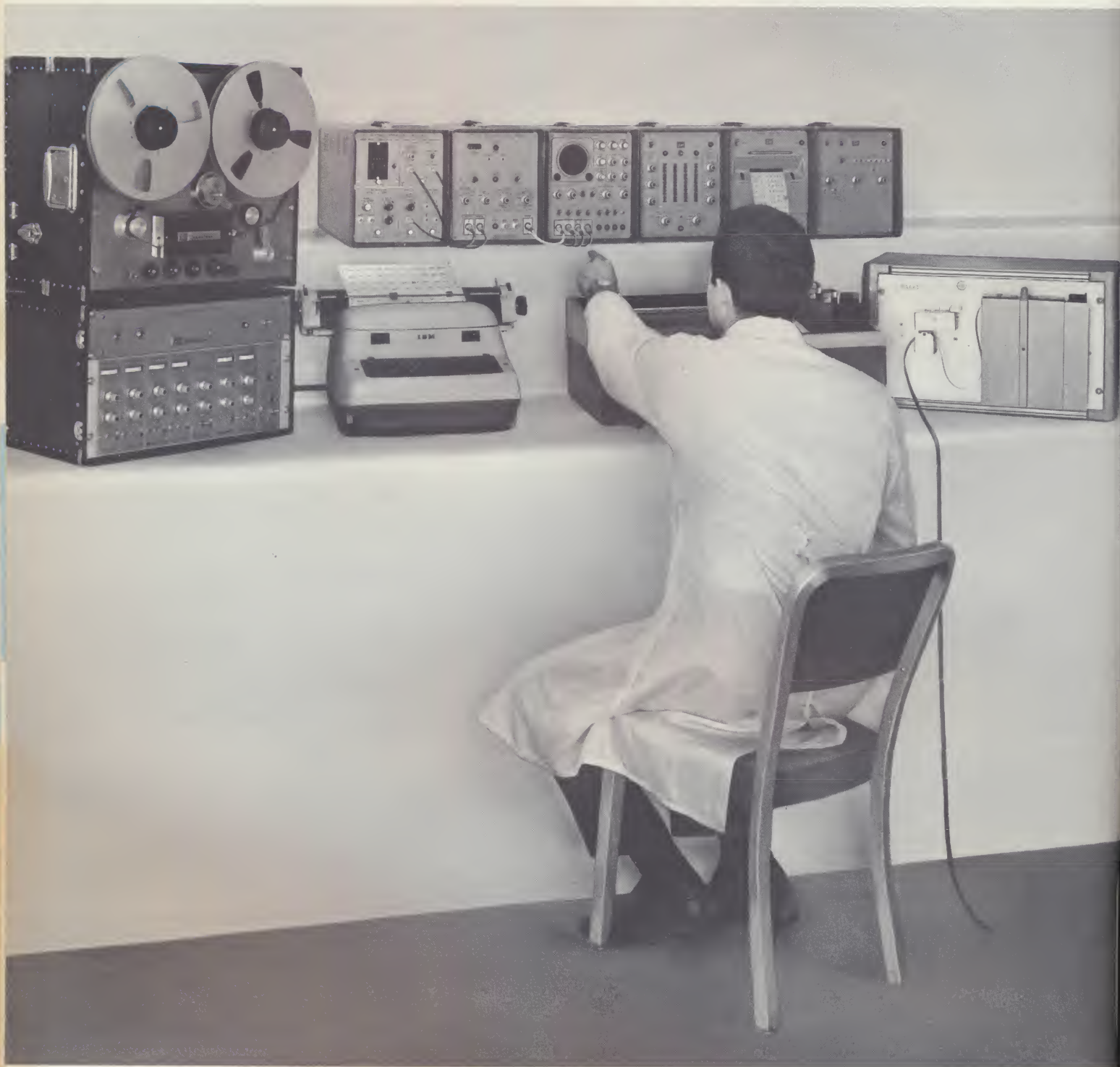
For a number of years, effective results have been obtained by the use of signal averaging techniques in the analysis of responses having seismic origins. One area successfully employing this technique is the exploration of oil deposits. For this application, a heavy weight (usually three tons or more) is dropped from a hydraulic lift. When it hits the ground, the kinetic energy developed from the falling mass creates sound waves which are transmitted through the surface of the earth and are reflected by discontinuities in its crust. These reflected waves are detected by very sensitive geophones. However, not only the waves of interest but also waves from miniature earthquakes, traffic from nearby towns, micro-seismic phenomena, and electronic instrumentation noise are detected. To isolate the desired waves of interest from the surrounding random activity, the CAT is of immeasurable assistance.

A reference pulse must be established and this is obtained through an inertial switch which is activated when the mass strikes the ground. The reflected sound wave signals created by the falling weight are received by the geophone, amplified and fed to the input of the CAT. This process is repeated as many times as required until the CAT provides a signal which can be analyzed and extracted from the overall process. This signal forms the basis for immediate interpretation and determination for seismic exploration of oil deposits.

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HISTOGRAM APPLICATIONS

Histograms are the result of techniques using the MNEMOTRON CAT and compatible MNEMOTRON Model 600 Accessories. They determine the statistical variability of input data using the CAT as a counting device. Results may be represented in diverse forms of amplitude or time interval histograms. In the case of amplitude histograms, counts proportional to the amplitude of the input signal are deposited in a memory location—or, a count is deposited in a memory location whose number is proportional to the amplitude of the signal. In the case of time interval histograms, counts proportional to the time interval of the input signal are deposited in a memory location—or, a count is deposited in a memory location whose number is proportional to the signal time interval. Hence, the investigator is supplied with a distribution curve of the signal source and can easily determine preferential amplitudes or time intervals. To obtain histograms, MNEMOTRON provides an Amplitude Discriminator Model 605, an Amplitude-to-Time Converter Model 606, a Peak Detector and Window Discriminator Model 607, and a Resolver Integrator Model 522.

A non-sequential histogram is a probability distribution function of a specific variable. It yields statistical data which permits the computation of the mean (average) as well as the standard deviation (spread) of the variable under investigation. The most frequently occurring variable is immediately determined from the CAT display.

In non-sequential histograms involving time as the variable, the incremental time may range from several microseconds to several days. The maximum resolution within one histogram is $1/400$ th of the longest time increment expected. In non-sequential histograms involving amplitude as the variable, the maximum resolution attainable is $1/400$ th of the maximum amplitude expected.

A sequential histogram differs from the non-sequential in that the resultant curve is no longer a distribution curve. Since the variable under investigation occurs as a function of time, it may be of interest to investigate the time order in which the variable occurs. The sequential histogram is a record of how the variable changes with time, and hence, can indicate time trends of the variable which could bias the non-sequential distribution histogram.

In sequential histograms involving time as the variable, the incremental time may range from less than a microsecond to several days. The maximum resolution within one histogram is one part in 10^5 (10^6 on request) of the longest time increment expected. In sequential histograms involving amplitude as the variable, the maximum resolution attainable is one part in 500 of the maximum amplitude expected.

HISTOGRAM APPLICATIONS

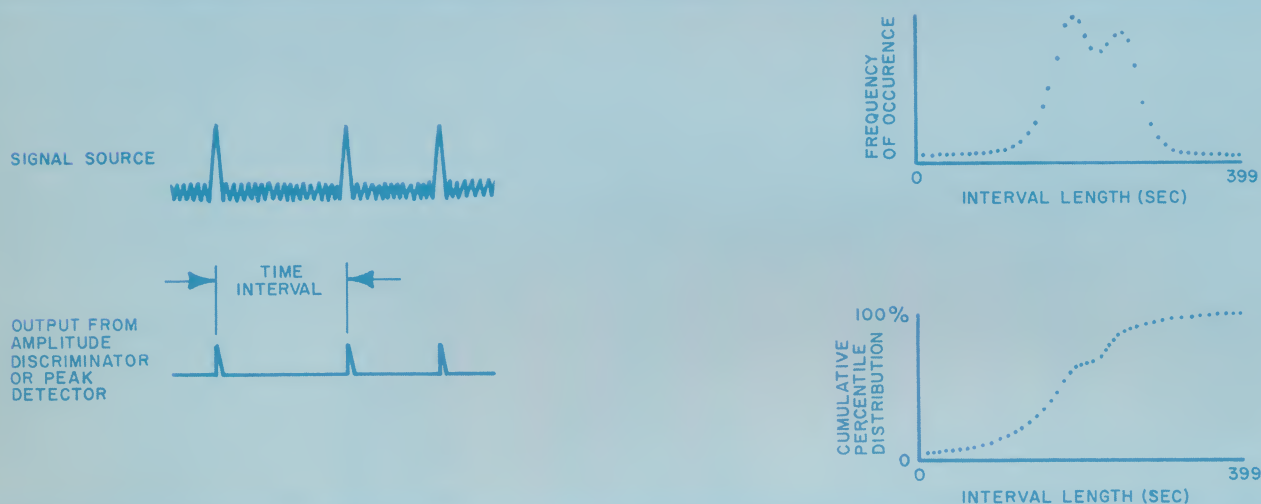
TIME INTERVAL HISTOGRAMS

• NON-SEQUENTIAL

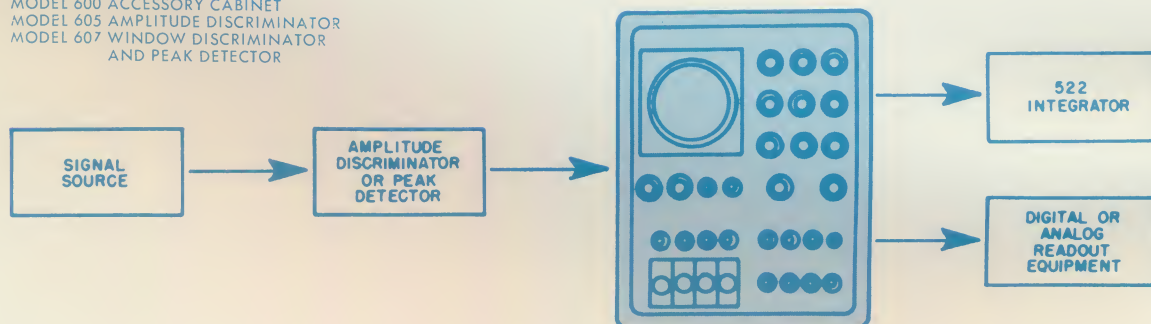
A non-sequential time interval histogram is the distribution of time intervals between specific events. The specific events may be pulses, specific amplitudes on an analog waveform (such as peaks of the waveform) or any other predetermined points of the input signal. Time interval histograms are of interest in such fields of application as cardiology for R-R intervals, neurology for interspike intervals, behavioral psychology for response times, to name just a few.

Through the use of MNEMOTRON accessories, intervals are determined either between points of each event of equal preselected amplitude or between the peaks of each event. A sweep is initiated by each event. At the occurrence of the next event, the sweep is terminated, a count is deposited at that memory location addressed when the sweep ends, and a new sweep automatically regenerated. Integration of this distribution curve by means of the Model 522 Integrator yields the cumulative distribution function which, when normalized, allows for the comparison of histograms of similar origin.

The figures show a typical interval probability distribution histogram and the integrated cumulative probability function.



ACCESSORIES REQUIRED:
MODEL 600 ACCESSORY CABINET
MODEL 605 AMPLITUDE DISCRIMINATOR
MODEL 607 WINDOW DISCRIMINATOR
AND PEAK DETECTOR



HISTOGRAM APPLICATIONS

TIME INTERVAL HISTOGRAMS

• SEQUENTIAL

In sequential time interval histograms, each CAT address indicates a successive time interval rather than a distribution of the interval times. Applications include all those listed under non-sequential time interval distribution curves and, in addition, learning time curves and adaption times curves.

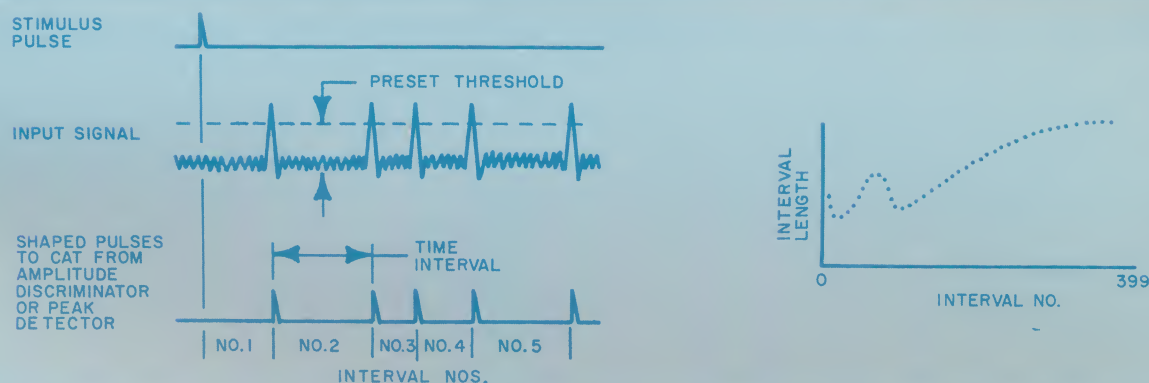
CAT data processing resulting in the interval curve can be initiated from a stimulator when required. In this case, the sequential interval curve is related to the time of occurrence of the stimulus.

The sequential time interval histogram presents the time interval between successive events as a proportionate number of counts in each successive address. This is accomplished by either the external stimulation or the first event initiating CAT operation. A pulse oscillator causes counts to be deposited into each CAT address while each event itself causes the address register to advance sequentially. As a result, a sequential time interval histogram is obtained of the time duration between successive events.

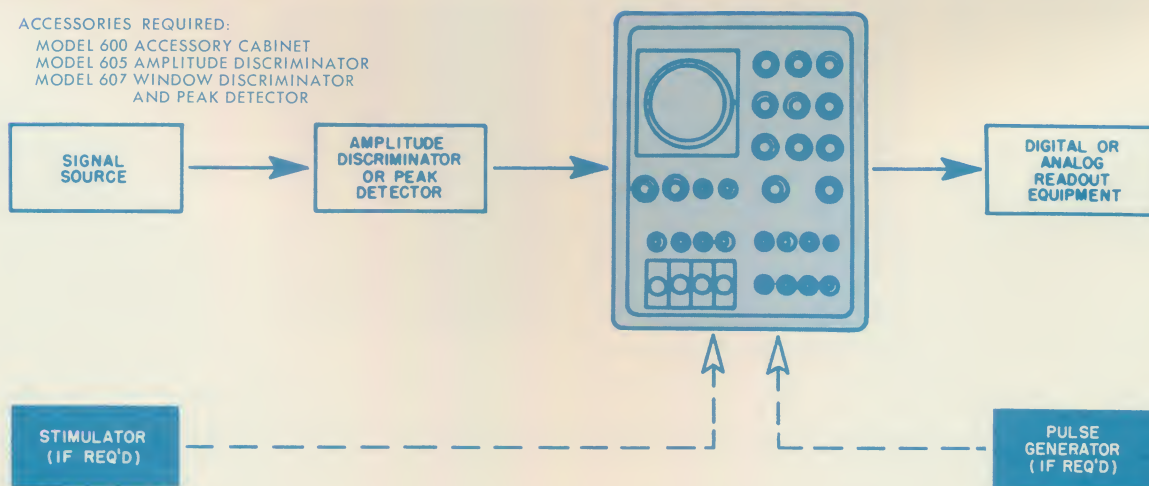
The illustration indicates a typical input signal with its associated sequential time interval histogram.

Use of the 522 Integrator in the subtotal mode can be made to indicate the total time over which the histogram was made.

The CAT 400B will indicate the interval between 400 sequential events.



ACCESSORIES REQUIRED:
MODEL 600 ACCESSORY CABINET
MODEL 605 AMPLITUDE DISCRIMINATOR
MODEL 607 WINDOW DISCRIMINATOR
AND PEAK DETECTOR



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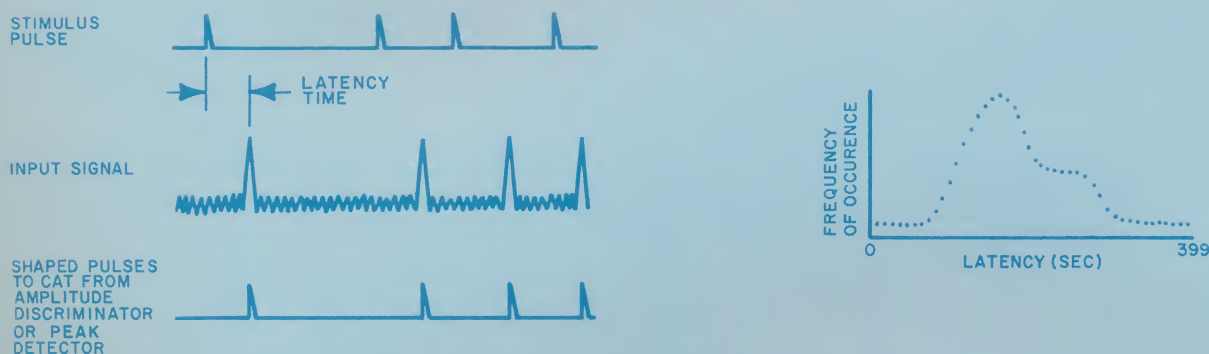
HISTOGRAM APPLICATIONS

LATENCY HISTOGRAMS

• NON-SEQUENTIAL

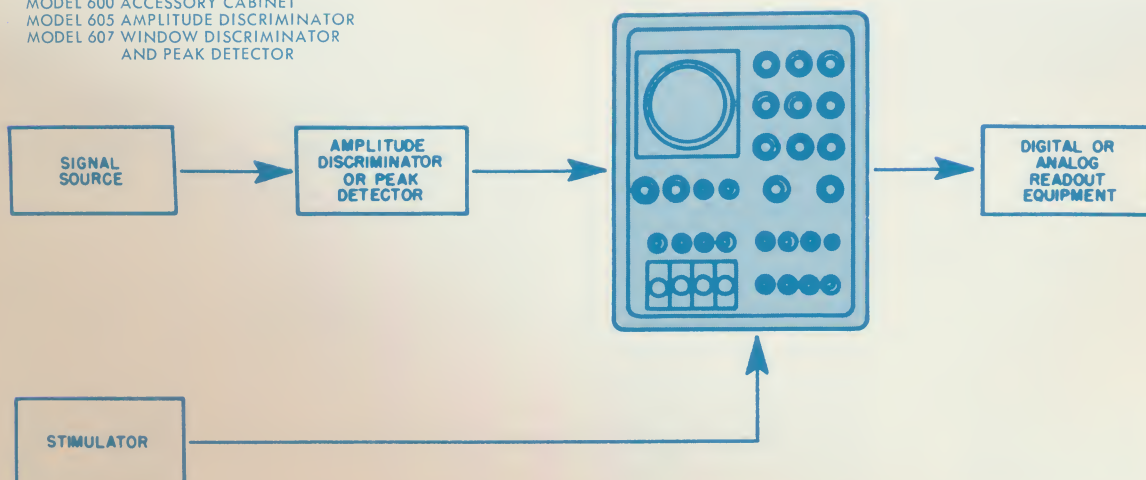
A non-sequential latency histogram is a distribution curve of the time interval between stimulation and the occurrence of the response. The response may be pulses or specific amplitudes on an analog waveform (such as peaks). Latency distribution curves are used for the determination of the time interval between subject stimulation and initial unit response in neurophysiology; reaction time between occurrence of event and subject response in behavioral psychology; time interval between subject stimulation and peak of evoked response in neurology. In general, latency histograms can determine the time interval between any two independent successive events as illustrated.

In this histogram application, the first event or stimulation serves as a trigger for the CAT and initiates the sweep through the memory addresses. The response or second event, properly shaped through the use of MNEMOTRON accessories, stops the sweep and causes one count to be deposited in the channel addressed at that instant of time. The CAT address is then reset to zero and awaits the next stimulation.



ACCESSORIES REQUIRED:

MODEL 600 ACCESSORY CABINET
MODEL 605 AMPLITUDE DISCRIMINATOR
MODEL 607 WINDOW DISCRIMINATOR
AND PEAK DETECTOR



HISTOGRAM APPLICATIONS

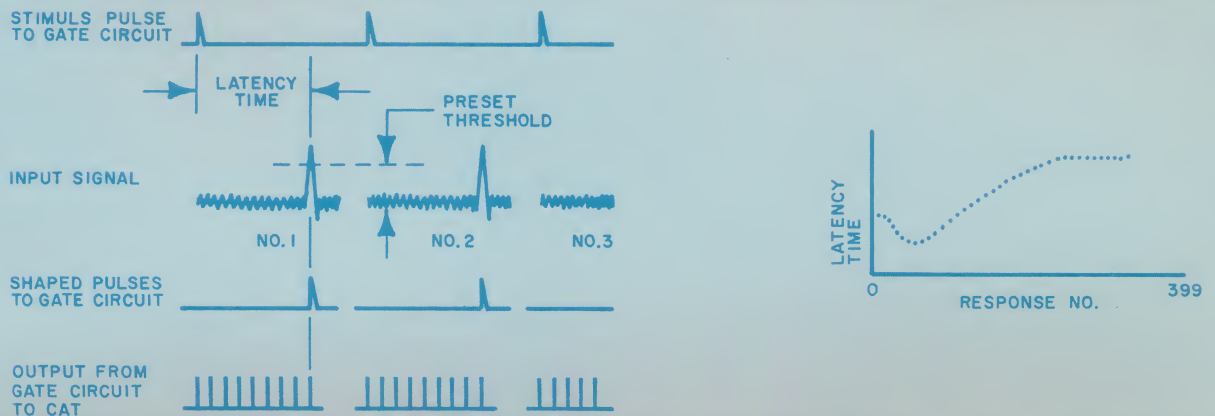
LATENCY HISTOGRAMS

• SEQUENTIAL

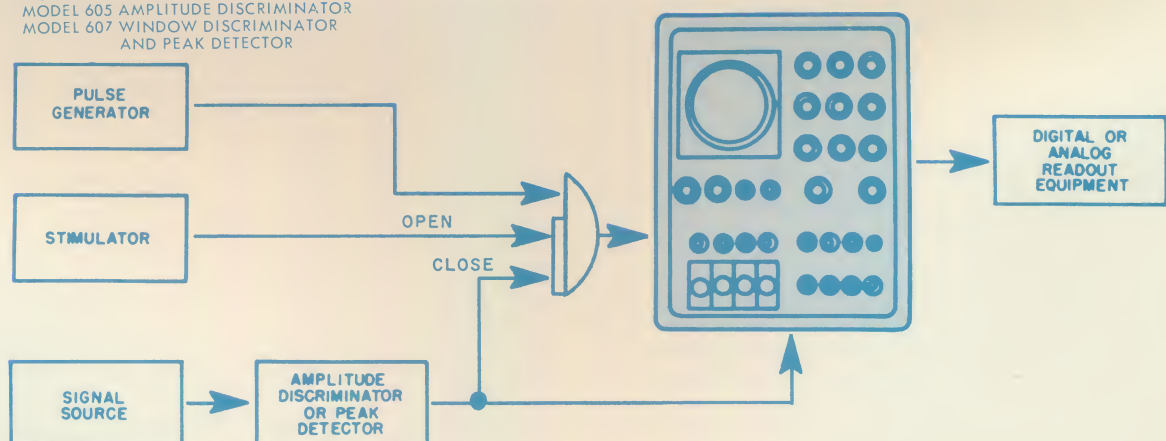
In sequential latency histograms, each CAT address indicates the time interval between successive stimulus/response pairs rather than a distribution of the latency times. In this application, up to 400 latency times may be accumulated. Sequential latency histograms can be used in all applications stated in non-sequential latency distribution curves in addition to learning time and adaptation time curves required in behavioral psychology.

As shown in the illustrations, the stimulus pulse or first event opens a gate circuit allowing pulses from a pulse generator to be deposited into a CAT address. The response or second event closes the gate circuit and advances the CAT one address to await the next stimulus. The number of pulses counted in any CAT address is proportional to the time interval between the stimulus/response pair. The next stimulus pulse reopens the gate circuit to repeat the counting operation. As a result, each address (up to 400) reflects time intervals between stimuli and their subsequent response.

The interval time as contained in any CAT address is calculated by dividing the number of counts in an address by the frequency of the pulse generator.



ACCESSORIES REQUIRED:
MODEL 600 ACCESSORY CABINET
MODEL 605 AMPLITUDE DISCRIMINATOR
MODEL 607 WINDOW DISCRIMINATOR
AND PEAK DETECTOR



TECHNICAL MEASUREMENT CORPORATION

MNEMOTRON DIVISION

TMC

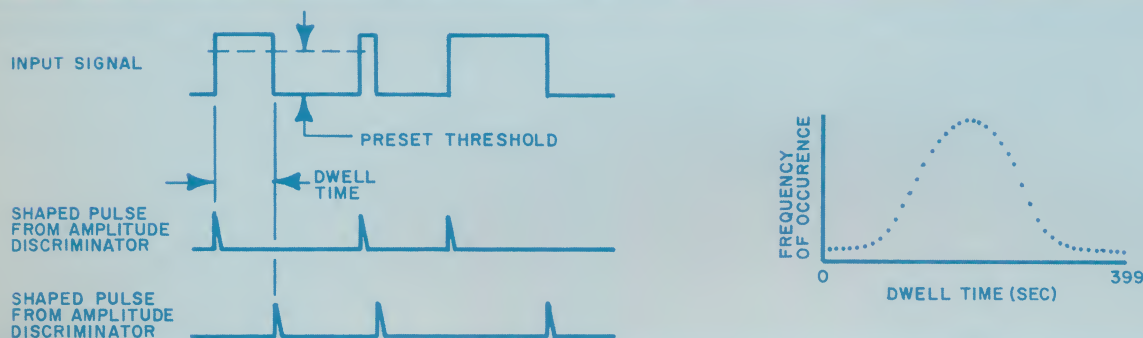
HISTOGRAM APPLICATIONS

DWELL TIME HISTOGRAMS

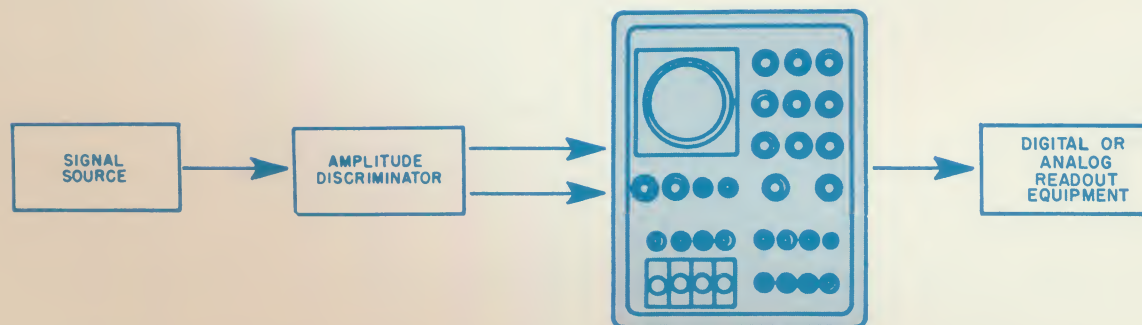
• NON-SEQUENTIAL

The non-sequential dwell time histogram is the distribution of the times that a waveform exceeds a preset amplitude level. Areas in which dwell time histograms are desirable are pulse width modulation studies where the width of the pulse is equal to the time the signal exceeds a preset amplitude and vibration or sound wave analyses to determine a distribution of the signal frequencies.

When the signal of interest exceeds the preset amplitude level as set on the MNEMOTRON accessory module, a sweep is started through the CAT addresses. The signal falling below the preselected amplitude level terminates the sweep and deposits one count in the channel addressed at that instant of time, and the CAT sweep is reset to the zero address. When the level is again exceeded, another sweep is initiated and the operation is repeated. As a result, a histogram is accumulated reflecting the frequency of occurrence of specific intervals during which the signal level exceeded the preset amplitude level, as illustrated.



ACCESSORIES REQUIRED:
MODEL 600 ACCESSORY CABINET
MODEL 605 AMPLITUDE DISCRIMINATOR



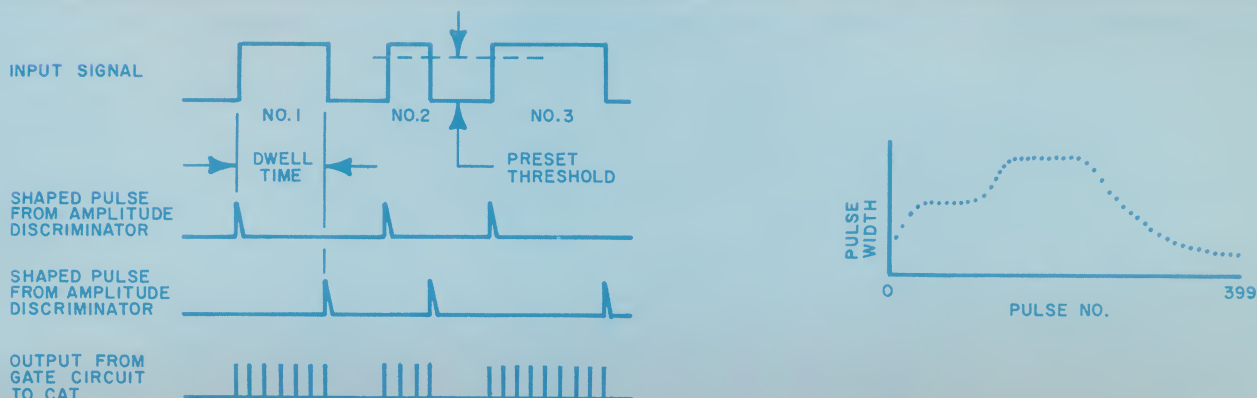
HISTOGRAM APPLICATIONS

DWELL TIME HISTOGRAMS

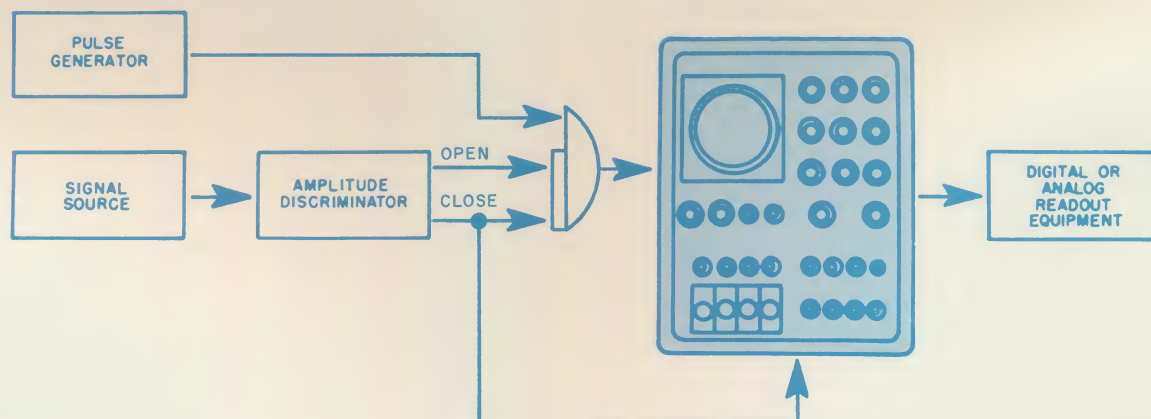
• SEQUENTIAL

In sequential dwell time histograms, each CAT address (up to 400) reflects the time that the input signal exceeds a preset level. Counts are deposited in successive addresses proportional to the time period for which a preset amplitude is exceeded. Pulse width modulation studies and vibration or sound wave analyses are possible applications in this area.

When the signal of interest exceeds the preset amplitude level, a gate circuit opens, allowing pulses from a pulse generator to be deposited in one address of the CAT. When the amplitude falls below the preset level, the gate circuit closes and the CAT is advanced one address to await the next dwell period sequence. The next time the preset level is exceeded, the gate circuit again opens to repeat the counting operation. The number of pulses counted in any CAT address is proportional to the dwell period. Each address up to 400 can reflect the time period in which the preset level is exceeded. The interval time as contained in any CAT address is calculated by dividing the number of counts in an address by the frequency of the pulse generator.



ACCESSORIES REQUIRED:
MODEL 600 ACCESSORY CABINET
MODEL 605 AMPLITUDE DISCRIMINATOR



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NEMOTRON DIVISION

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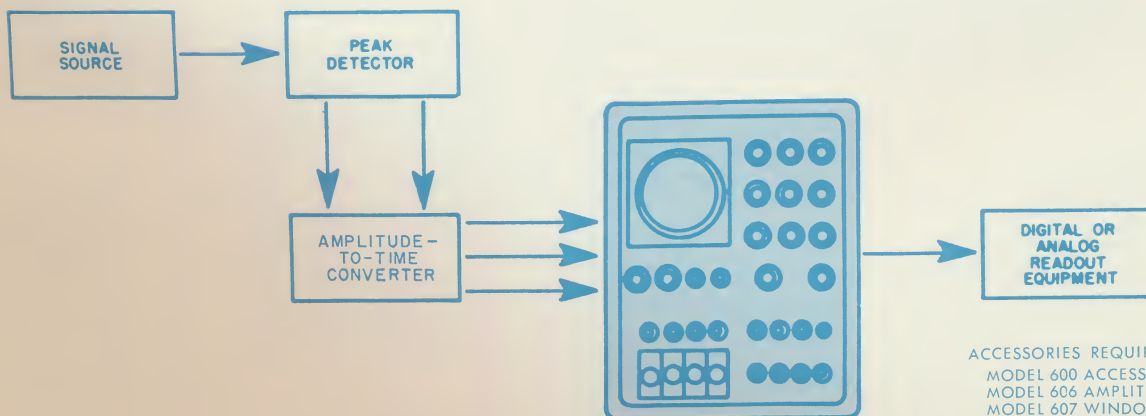
HISTOGRAM APPLICATIONS

AMPLITUDE HISTOGRAMS

• NON-SEQUENTIAL

A non-sequential amplitude histogram is the distribution curve of the peak amplitudes of an input signal waveform. Applications for amplitude histograms include cell size distribution curves in hematology and biochemistry, R-wave amplitudes in cardiology, and unit discharge amplitudes in neurophysiology.

For example: cell size counters will produce a series of pulses whose amplitudes are proportional to the cell sizes. To obtain a distribution curve of these pulse amplitudes (cell sizes), the pulse peaks are detected, held and sampled. At the detection of the peak, a CAT sweep is initiated; the addresses are advanced; after a period of time proportional to the peak amplitude, the sweep is terminated; and a count is deposited in the channel addressed at that instant of time. The CAT sweep resets to address zero and awaits the detection of the next peak. The next peak that occurs initiates a new sweep and the operation is repeated. As a result, a non-sequential amplitude histogram is obtained which plots the frequency of occurrence of specific peak amplitudes and therefore cell size distribution curves.



ACCESSORIES REQUIRED:
MODEL 600 ACCESSORY CABINET
MODEL 606 AMPLITUDE-TO-TIME CONVERTER
MODEL 607 WINDOW DISCRIMINATOR
AND PEAK DETECTOR

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